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# THE WORLD INNOVATION LANDSCAPE: ASIA RISING?

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## Highlights

- Research and development spending has risen rapidly in Asia, particularly in China, which is now the world's second R&D spender behind the United States. The increase in Korean and Chinese patent applications has been even more rapid, but Chinese patenting for exploitation on the main markets for innovation (the European Union, Japan and the US) is still marginal.
- Asia's increased innovation spending is most prominently related to information and communication technologies. Overall, the Chinese and Korean economies are still not specialised in knowledge-intensive goods and services. Furthermore, China in particular is not (so far) capturing much value from its role as a manufacturer and exporter of high-tech goods; China remains mostly an assembler of goods, the value of which is created elsewhere.
- It would be wrong to ignore China's innovation potential on the basis of its current performance. Its clear innovation ambitions are likely to drive its future growth.
- Europe is struggling much more than the US to retain its place at the global innovation table. The EU should use Asia's capacity building in innovation as an opportunity for value capture.

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# THE WORLD INNOVATION LANDSCAPE: ASIA RISING?

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GROWTH IN RESEARCH AND DEVELOPMENT SPENDING GLOBALLY has been vigorous, averaging nearly eight percent annually during the last five years[1]. An ever-larger group of governments is making innovation a national priority. At the same time, private R&D investment is also increasing worldwide, and is growing more rapidly outside the previously dominant centres of North America, Europe and Japan.

This growing global public and private science, technology and innovation capacity and capability presents both opportunities and challenges to Europe. Increased globalisation of science, technology and innovation resources offers opportunities for cross-border collaboration. The pool of researchers is larger, there is more potential for utilisation of major foreign research facilities and there are larger markets for innovative goods. However, globalisation of innovation also challenges Europe's competitiveness in high-technology areas, and its position in critical science, technology and innovation fields.

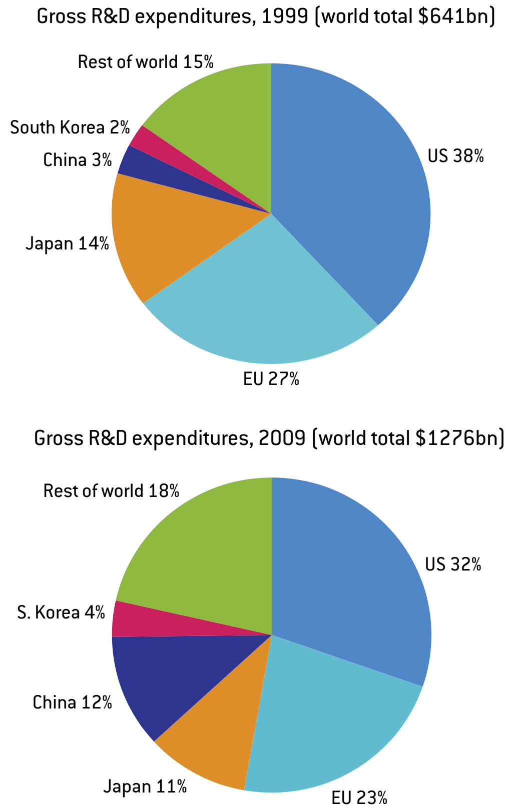
## GLOBAL PATTERNS OF R&D EXPENDITURE: THE RISE OF ASIA, IN PARTICULAR CHINA

Within the global growth of R&D expenditure, there is a major trend of rapidly rising spending in Asia. The R&D performed in Asia represented only 24 percent of the global R&D total in 1999. By 2009, Asia accounted for 32 percent, compared to 34 percent for North America, and overtaking the EU, which accounted for 23 percent total global R&D in 2009, down from 27 percent in 1999 (Figure 1).

This trend is even more striking when looking at specific countries. The United States is by far the biggest spender on R&D ($402 billion in 2009), accounting for about 32 percent of the global total. But the US share (not volume) is in decline, having stood at 38 percent in 1999. The country making the most spectacular inroad is China, which by 2009 was the second biggest spender ($154 billion), accounting for about 12 percent of the global total. Its R&D expenditure is now similar to that of Germany, France and Italy combined. Japan has been pushed into third place, at 11 percent ($138 billion). The top-ranking EU countries spend less: Germany ($83 billion, 7 percent), France ($48 billion, 4 percent) and the United Kingdom ($40 billion, 3 percent). Another Asian entry in the top group is South Korea, representing 4 percent of

1. Growth in nominal worldwide R&D expenditures, NSF (2012) on the basis of UNESCO.

**Figure 1: Global investment in R&D, selected countries share of total, 1999 and 2009**




| Average annual growth rate, 2000-09 | | | | |
|---|---|---|---|---|
| US | EU | Japan | China | Korea |
| 5.1 | 5.8 | 4.1 | 22.4 | 12.1 |

Source: Bruegel based on National Science Foundation data (NSF, 2012). Note: R&D expenditures are nominal, expressed in $, PPP; 2009 data for South Korea estimated from 2008 on the basis of average annual growth rate 2005-08. EU = EU27.

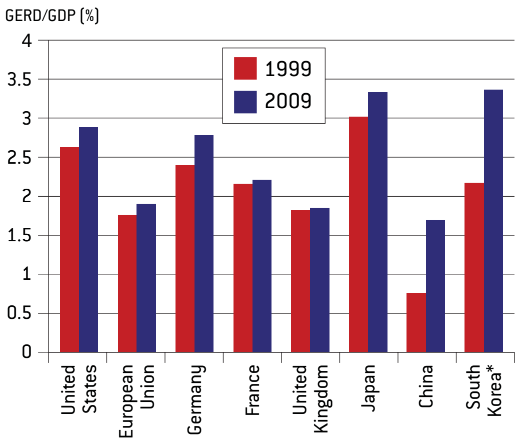
the global total ($44 billion). Taken together, these top seven countries account for about 71 percent of total worldwide R&D expenditure (we will list them as the *Global Research 7* – GR7).

Italy ($25 billion) and Spain ($20 billion) do not belong to the group of major R&D spending countries. The Scandinavian countries, Sweden, Finland and Denmark, even when taken together, still represent only $26 billion.

China's current second position is a consequence of spectacular R&D spending growth. The pace of real growth in overall R&D in China from 1999-2009 was exceptionally high at about 22 percent annually. The rate of growth in South Korea's R&D spend has also been relatively high, averaging 12 percent annually over this 10-year period.

By comparison, while the US remains top of the list of the world's R&D spenders, its rate of growth in R&D spending averaged 5 percent from 1999-2009, which explains its relative decline (though it still comprehensively outspends any competitor). Growth in Japanese spending was even slower, at an annual average rate of 4 percent. The rate of growth during the same period for the EU as a whole was 6 percent.

**Figure 2: Gross R&D expenditures as % of GDP, selected countries, 1999 and 2009**




Source: Bruegel based on National Science Foundation data (NSF, 2012). Notes: GERD = gross expenditure on R&D.
* South Korea, 1999 and 2008.

The major increase in Chinese R&D spending is even more remarkable when compared to its already impressive GDP growth rate. Trends in R&D-to-GDP ratios (R&D intensity) express R&D patterns relative to the size and growth of the economy.

By this measure, Asia stands out as the region in which R&D spending has grown faster than GDP, resulting in a greater R&D intensity. China's R&D-to-GDP ratio has more than doubled from 0.8 percent in 1999 to be 1.7 percent in 2009, and is almost on par with other GR7 countries, such as the UK. Another fast Asian riser is South Korea, which, together with Japan, is the GR7 country with the highest R&D-to-GDP ratio, greater than 3 percent. In contrast to China and Korea, Japan's increase in R&D intensity is due to a slow down in GDP growth below the growth in R&D expenditure. The US has a high R&D intensity, but its growth in R&D intensity has been much more modest.

The EU on average performs only modestly when measured by R&D intensity: 1.9 percent in 2009, well below the EU's Horizon 2020 target of 3 percent. This is despite the stellar Scandinavian performances (Finland 4 percent, Sweden 3.6 percent, Denmark 3 percent), but due to some large EU countries with low scores, such as Spain (1.4 percent) and Poland (0.7 percent). Particularly striking is Italy, which has an R&D intensity of 1.3 percent. Though a member of the G7, it is far from qualifying for the GR7 group. The UK (1.9 percent) and France (2.2 percent) also have relatively low R&D intensities, and have exhibited only modest increases in R&D intensity. Germany (2.8 percent) has increased its R&D intensity to be on par with the US (Figure 2).

Some other R&D-intense Asian countries outside the GR7 group are Singapore (2.3 percent) and Taiwan (3 percent). India with 0.8 percent does not belong to the club of Asian R&D tigers. The other BRIC countries, Russia (1.24 percent) and Brazil (1.1 percent), are also minor R&D players.

*'China's R&D spending growth has been spectacular. The pace of real growth in overall R&D expenditure in China from 1999-2009 was exceptionally high at about 22 percent annually. By comparison, the US's R&D spending growth averaged only 5 percent from 1999-2009.'*

## WHAT IS BEHIND ASIAN R&D SPENDING GROWTH?

The business sector is the main spender on R&D in all GR7 nations. This does not diminish the importance of governments as drivers of R&D trends. Public investment in science and technology is, when successful, an enabler of subsequent R&D performance within the private sector. And the state influence in private companies can be substantial.

### *The state as financier of R&D*

Table 1 shows the share of total R&D expenditure financed by the public sector. Perhaps contrary to expectations, Asia has a lower share of R&D funding accounted for by the government than the US and Europe. About 75 percent of Japan's total national R&D came from the business sector. For Korea it is 73 percent, and for China 72 percent. In contrast, in the United Kingdom (33 percent), Germany (28 percent), and United States (31 percent) the share of state financing in R&D is high. France has the largest public share among GR7 countries (39 percent).

The common conjecture that Asian R&D is mostly government funded (or performed) is thus not confirmed by the data. That of course does not preclude the importance of government influence in instigating private R&D. Many of China's large private companies are state controlled or influenced.

GR7 governments differ significantly in what they spend their R&D budgets on, reflecting different government R&D priorities (eg, defense, health, general non-directed research) Comparable data for China is unfortunately not available.

Defense has been for much of the past quarter century, and continues to be, the focus of more than half of the US federal R&D budget. France also spends more than one quarter of its public R&D budget on defense. Within the non-defense federal US R&D budget, health has expanded dramatically and accounted for in 2009 more than a quarter of the federal R&D budget. Japan is the country with the highest government outlays on energy R&D. South Korea concentrates its biggest share on industrial technology. The 'other' category includes general funding to universities, which is typically non-targeted.

Overall the data does not support the notion that the rise of Asia in R&D is driven by direct government spending. It does show however a different profile of sectors targeted by government-funded R&D. And it does not exclude government influence in private sector R&D, particularly in China.

## WHICH SECTORS ARE DRIVING ASIAN R&D GROWTH?

Because businesses account for the largest share of total R&D spending in most countries, differences in business structure go a long way to help explain international differences in trends in R&D-to-GDP ratios. Countries that specialise in dynamic high-tech sectors (such as pharmaceuticals and ICT) are more likely to also have higher and

**Table 1: Share of government in R&D expenditure and government budget appropriations by socioeconomic objective, selected countries, 2009 or most recent year**

| | Government spend as % of total R&D | Share of government budget by objective (%) | | | | |
|---|---|---|---|---|---|---|
| | | Defense | Industr. prod. & tech. | Health | Energy & environment | Other* |
| US | 31.3 | 51.6 | 0.6 | 26.7 | 2.7 | 18.4 |
| Germany | 28.4 | 5.7 | 12.7 | 4.8 | 7.2 | 69.6 |
| France | 38.9 | 28.3 | 8.6 | 7.1 | 8.7 | 47.3 |
| UK | 32.6 | 18.3 | 2.4 | 18.2 | 3.7 | 57.4 |
| Japan | 17.7 | 3.7 | 8.4 | 4 | 14.1 | 69.8 |
| China | 23.4 | n.a. | n.a. | n.a. | n.a. | n.a. |
| South Korea | 25.4 | 16.7 | 26.5 | 8.7 | 12 | 36.1 |

Source: Bruegel based on National Science Foundation (NSF, 2012). Note: * Other (share of government budget by objective) includes the non-targeted area of *general advancement of knowledge* (university funding) and other targeted areas such as earth and space, transport, telecommunications, agriculture, education, culture, political systems.

increasing R&D-to-GDP ratios than countries in which the business structure is weighted more heavily towards slower growing low- or medium-tech industries. Europe's failure to increase its R&D-to-GDP ratio is often attributed to its failure to specialise in high-tech sectors (see for example previous Bruegel *Policy Briefs*: Van Pottelsberghe, 2008, and Veugelers and Cincera, 2010).

Compared to the US, which has a broad spread across sectors, smaller economies in Asia show much higher concentrations of R&D spending in particular industries. For example, in South Korea, the ICT industry, which includes semiconductors, accounted for 46 percent of the country's business R&D spend. The share of ICT spending in Singapore and Taiwan is similarly big. The rise of the Asian R&D tigers therefore correlates with the industrial focus on R&D in the ICT sector.

A significant trend within the growth in US business R&D spending has been the growth of spending by the service sector, accounting for 32 percent of all business R&D expenditure in 2009 (14 percent for computer-related services). Services also account for about one quarter of all private R&D spending in the UK. In Asia, the services sector is still less predominant in business R&D, representing 11 percent or less of spending in Japan, China and South Korea.

## DOES THE GROWTH IN ASIAN R&D SPENDING TRANSLATE INTO GROWTH IN ASIAN INVENTIONS?

How efficient is the new Asian R&D investment? Is it resulting in a new generation of inventions and sources of growth?

Patents are regarded as a good proxy for innovation, despite a wide-ranging debate on whether they encourage or hinder innovation (eg Harhoff, Scherer and Vogel, 2003). Given the requirements for a valid patent (novelty, utility and non-obviousness) they are an important step as inventions progress towards commercialisation. In addition, their licensing may provide an important source of revenue. However, not all inventions are patented. The propensity to patent varies by industry and technology area. In addition, patents suffer from a 'truncation' problem, with the most recent trends not available, in view of the time it takes to process patent applications. The patent data source that suffers least from the time lag issue is Patent Cooperation Treaty (PCT) applications[2].

In line with the rise in global R&D expenditure, total PCT applications have been rising continuously (6 percent average annual growth rate, 1999-2009). But within this overall rise in patenting, there are significant regional differences (Figure 3 on the next page). The dominant position of the US in patenting is gradually eroding. While the EU has been able to match, and even slightly outpace, the US in patenting, it is, like the US, gradually ceding share to Asia. Among Asian countries, Japan is the most important patenting country, and has consistently increased its share of PCT applications. The rise of China is, like R&D expenditure, clear to see, albeit from a very low level. Perhaps most notable in terms of patenting growth is South Korea, which produces, despite its smaller size, a similar number of patents to China.

Table 3 compares the trends in countries' share of global patents relative to R&D. A ratio greater than 1 (ie the country has a greater share of world

**Table 2: Private R&D expenditure by selected industry and country (%), most recent year.**

| Industry | France 2007 | Germany 2008 | Japan 2009 | S. Korea 2008 | UK 2008 | US 2009 | China 2009 | Singapore 2009 | Taiwan 2009 |
|---|---|---|---|---|---|---|---|---|---|
| Pharma | 14.3 | 7.4 | 10 | 2.4 | 27.2 | 15.9 | 3.2 | 0.6 | 1.4 |
| Machinery & equip.: | 52.2 | 67.7 | 59 | 73.1 | 37.1 | n.a. | 49.2 | 66.9 | 81.6 |
| ICT | 10.4 | 7.1 | 16.8 | 45.7 | 4.2 | 12.5 | n.a. | 59.4 | 53.1 |
| Cars | 14 | 32.8 | 15.6 | 13.2 | 7.9 | 4.6 | n.a. | 1.6 | 1.7 |
| Services: | 12.3 | 10.3 | 11.2 | 7.9 | 24.7 | 32.3 | 7.3 | 26.7 | 7.3 |
| Computing | 7 | n.a. | 2.1 | 3.4 | 9.4 | 14.2 | n.a. | 2 | 3 |
| R&D | 0.2 | 2.7 | 5.6 | 0.4 | 2.5 | 6.9 | n.a. | 9.5 | 0.5 |

Source: National Science Foundation (NSF, 2012).

2. The Patent Cooperation Treaty (PCT) provides a framework for filing patent applications to protect innovations in each signatory country. The PCT offers the possibility to seek patent rights in a large number of countries by filing a single international application with a single patent office (receiving office). Applicants have an additional 18 months to decide whether to seek a national or regional (eg European Patent Office) patent; if they so wish, they must do so within 30 months of the priority date (an average of 60 percent of PCT filings enter the EPO regional phase). The PCT procedure is increasingly used for patent applications, strongly correlated with an increasing number of contracting states.

patents than of world R&D expenditure) could be interpreted as reflecting a more efficient R&D process. One should however be careful in cross-comparing patents and R&D; some countries might have a specialisation in sectors with a higher propensity to patent, such as pharmaceuticals. Nevertheless, the trends in the ratio are interesting, as industry structures do not change quickly. Table 3 shows that the rise in patenting in China, Japan and South Korea has outpaced their increased R&D spending. For Japan and South Korea, this has reversed a position whereby their share of world R&D expenditure was much lower than their share of world patenting. Their share of world patents is now almost twice as high as their share of world R&D expenditure. For China, although its rising share of world patents has outpaced its rising share of world R&D spending, its share of world patents is still only half as large as its share of world R&D spend.

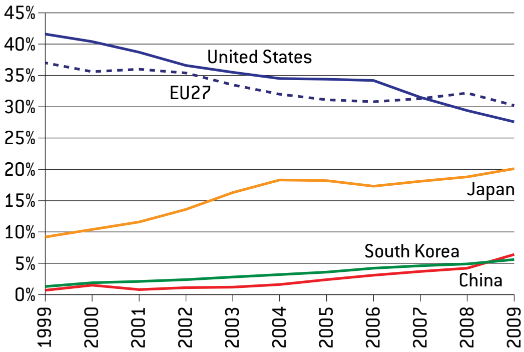
## IS THE INCREASE IN ASIAN PATENTED INVENTIONS MAINLY AN INCREASE IN LOW-VALUE PATENTS?

There is a huge heterogeneity in the quality of patent applications. Only a small minority of patents prove to be of high value. Harhoff, Scherer and Vogel (2003), for example, estimated for different samples of company and university patents, that 10 percent of the patents were responsible for 48-93 percent of the total economic returns. If the growth in total patent applications from a country is concentrated in the long tail of low-value patents, there may be limited innovation-based value creation.

There are various indicators used in the literature to measure the value of patents[3]. The measure we use is triadic patents, ie patents that are applied for in all three major regions: the US, Europe and Japan. Inventions for which patent protection is sought in all of these markets are likely to be viewed by their owners as justifying the high costs of filing and maintenance.

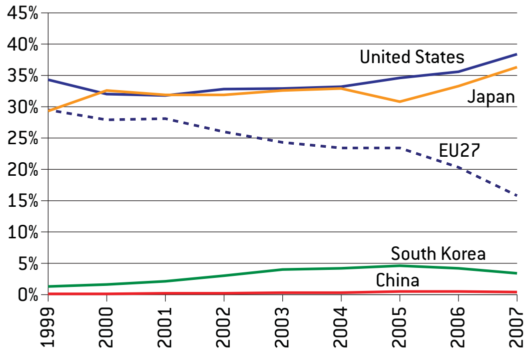
The pattern and trends for triadic patents are different to those for all patents. The dominant position of the US in triadic patents is not eroding over time. Japan's position in triadic patents also remains strong. The EU, however, has a lower share of triadic patents than overall PCT applications, and the EU's share is declining rapidly. Korea's performance in triadic patents is similar to its overall patenting performance, revealing no

Figure 3: Countries' shares of world PCT applications, 1999-2009




Source: Bruegel based on OECD. Note: country is by applicant; measuring the country by the location of the applicant versus the inventor for PCT applications gives very similar results.

Figure 4: Countries' shares of total triadic applications, 1999-2007




Source: Bruegel based on OECD. Note: triadic applications are patent applications filed at the EPO (European Patent Office), the USPTO (United States Patent and Trademark Office) and the JPO (Japan Patent Office) for the same invention.

Table 3: Patenting trends relative to R&D trends, % of world PCT filings relative to % of world R&D spend

| | US | Germany | France | UK | Japan | China | South Korea |
|---|---|---|---|---|---|---|---|
| 1999 | 1.1 | 1.7 | 0.9 | 1.3 | 0.6 | 0.2 | 0.6 |
| 2009 | 0.9 | 1.5 | 1.2 | 1.0 | 1.8 | 0.5 | 1.9 |

Source: Bruegel based on OECD.

3. Most of these measures, such as forward citations received, patent renewals or opposition to patents, are substantially correlated, including our measure: triadic patents.

specific high- or low-quality bias. China's position however is markedly different. The rise of China is much less evident when triadic patents are considered, compared to the growth rate in overall patenting in China. This indicates that growth in the production of Chinese inventions does not so far have a strong international orientation.

## WHICH TECHNOLOGIES ARE DRIVING THE ASIAN PATENT GROWTH?

The opportunities for technological innovation and hence new patent applications vary substantially across technologies. The 'hottest' areas with the greatest scope for new technology developments include biotechnology, ICT, nanotechnology and clean energy. The dynamic patent performance of countries – whether they increase or not their share of global patents – will depend to a great extent on how strong they are in these technology growth areas.

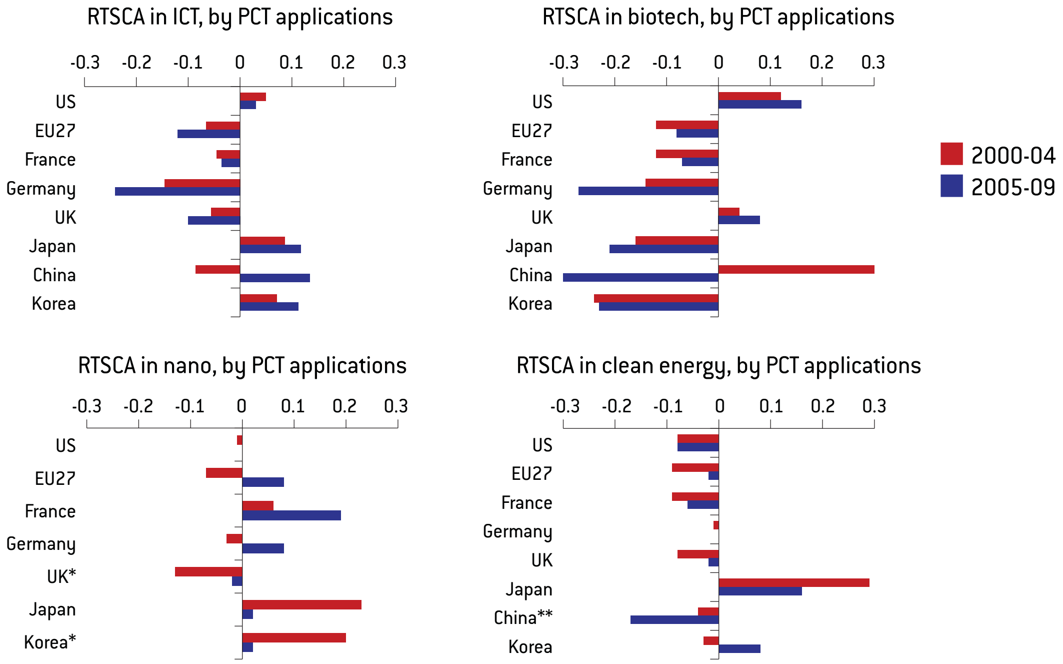
The EU27 as an aggregate does not specialise in any of the selected growth areas, with the recent exception of nanotechnology, in which Germany and France are building up a technology strength. The UK specialises in biotechnology. In clean energy, the EU does not yet hold a technology advantage, although it is making progress. Particular attention should be paid to the weak and deteriorating position of the EU in ICT.

It is in ICT in particular that Asia is building up its technology strength. This holds for Japan, South Korea and China, and correlates with the concentration of R&D investment in these countries in this area, and their science focus on engineering, physics and chemistry (Veugelers, 2011). Confronted by this rising Asian ICT power, the US remains strong in ICT, though its position is eroding.

In the other selected growth areas, the rise of Asia is less clear-cut. Biotech is a clear US strength, and is not an Asian relative stronghold. Nanotechnology is still very much early stage and volatile in terms of technology specialisation patterns. In clean energy, Japan has a strong hold, although this is gradually eroding, while South Korea is building up a strong position in this field.

Although China has ambitions in all technology growth areas, for the moment, it is only in ICT

Figure 5: Trends in specialisation in selected technology growth areas by major regions, revealed symmetric technology comparative advantage index (RSTCA), 2000-09




Source: OECD. Note: for a description of the RSTCA calculations, see Annex 1. * fewer than 250 patents in both periods; ** fewer than 250 patents during 2005-09. RSTCA in the nano sector for China has not been included because the number of patents during the period is too small for a reliable estimate of the indicator.

patents that it is realising its growth ambitions.

## TRANSLATING INVENTIONS INTO ECONOMIC VALUE CREATION

In this section we look at the impact of R&D spending and patents on countries' competitiveness. We examine the downstream effects of R&D spending and patent filings on the economies of the GR7. For this analysis, the performance of the GR7 in knowledge- and technology-intensive (KTI) sectors is the target of interest, as these sectors are considered to have a particularly strong link to science and technology. It is in these sectors that the impact from developments in science and technology is most strongly and most immediately felt. For a definition of KTI sectors, see Annex 2.

We are particularly interested in whether the Asian rise in share of world R&D spending and patenting activity translates into an increase in Asian producers and exporters of KTI goods and services.

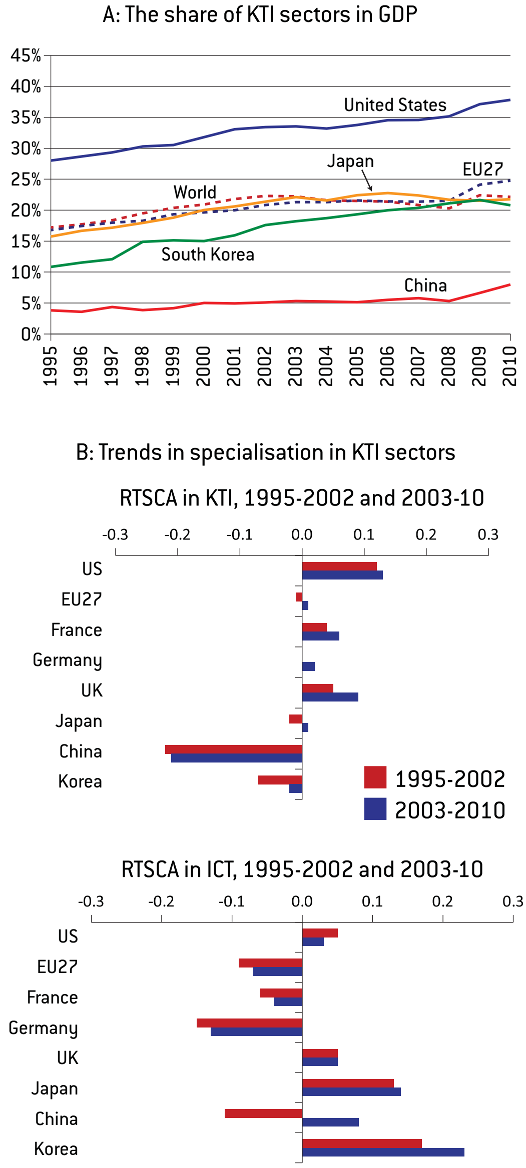
KTI sectors are becoming more important for a country's economic performance because they are responsible for a large and growing share of total value added. Global value added from these industries totaled $18.2 trillion in 2010 (NSF, 2012). This represents 30 percent of estimated world GDP, compared with a 27 percent share of a much smaller global economy 15 years earlier.

In addition, in many cases, KTI sectors develop technological infrastructure that diffuses across the entire economy. In particular, ICT is widely regarded as a transformative 'platform' technology, which is why we pay particular attention to ICT in this section.

In common with the growth in science publishing, R&D spending and patenting, Figure 6 clearly shows that for all regions KTI sectors are taking an increasing share of GDP. In 2009, KTI sectors were by far most prominent as a share of the US economy (40 percent). The KTI sector share is lowest in China (20 percent), and China is the least specialised in KTI sectors. Its emerging KTI sectors are dwarfed by low-tech activities. The EU (32 percent) and Japan (30 percent) are middling performers in terms of the share of KTI sectors in their economies, and they exhibit no particular specialisation. The average for Europe masks significant intra-EU heterogeneity. France, Germany and the UK all specialise in KTI. South Korea has done its catching-up and its KTI sectors have a similar share to those in the EU and Japan (29 percent). But like China, South Korea is still not specialised in KTI sectors, although it is slowly progressing.

When we single out ICT sectors (manufacturing and services) within KTI sectors (Figure 6, panel

**Figure 6: KTI sector trends**




Source: Bruegel based on National Science Foundation data. (NSF, 2012). Note: RSVCA (revealed symmetric value added comparative ddvantage) index is positive when a country specialises in KTI (ICT) sectors, as measured by having a share in world value added of KTI (ICT) sectors that exceeds its share in world valued added of all sectors. See Annex 1 for a technical description.

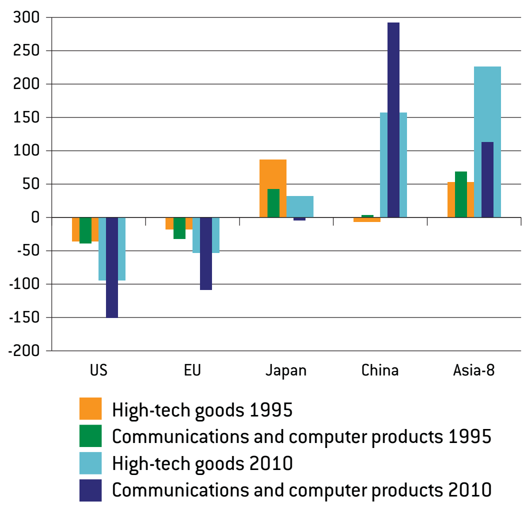
B), we see that China has made progress and has managed to develop a substantial specialisation in ICT. Japan and Korea were already specialised in ICT. Korea in particular has become more specialised over time. This increasing specialisation of Asian economies in ICT should not come as a surprise, given their major build up of science, R&D and technology capacity in this area[4].

Commonly used indicators for measuring the competitiveness of nations in knowledge-intensive sectors are their shares of high-tech goods in total exports, their shares of world export markets for high tech goods and their trade balance in these sectors (see for example, European Commission, Innovation Union Scoreboard and Competitiveness Report; NSF, 2012). Table 4 shows the share of the world market for high-tech goods of selected countries and regions. It confirms China's dramatic rise and Japan's fall, with Asia-8 (India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan and Thailand) consistently strong. The US and EU have seen their shares of high-tech export markets slowly erode. This is mainly explained by ICT sectors. The EU and US remain the leaders in pharmaceuticals.

Figure 7 shows the trade balance position for high tech goods. It confirms the gradual erosion of the positions of the US and the EU in high-tech goods; both have built up a negative trade balance in high-tech products, while China and the Asia-8 group have built up positive trade balances in high-tech. Japan still has a positive trade surplus, but this is slowly eroding. These shifts in trade position are most apparent for ICT.

In trade statistics, the full value of the traded good is credited to the source country. This creates a distorted picture for those goods that are merely assembled in the source country, and for which high value inputs and components are imported from other countries. The rise of global value chains and international vertical specialisation have made the foreign content embedded in gross export flows increasingly important, leading to a growing divergence between gross exports and domestic value added exports (eg Koopman *et al*, 2010; IMF, 2011). Properly factoring in the import content of exports would reduce the weight of the countries where assembly is carried out. For example, calculations on the basis of IMF (2011) indicate that China's domestic value added exports in all sectors would only be 58 percent of gross exports in 2005, for Korea, the figure would

**Figure 7: Trade balance in high-tech goods and communications and computers, selected countries, 1995 and 2010, $ billions**




Source: Bruegel based on National Science Foundation data (NSF, 2012).

**Table 4: Shares of world exports of high-tech goods, selected countries, 1995 and 2010**

| | ICT | | Pharmaceuticals | | All high-tech | |
|---|---|---|---|---|---|---|
| | 1995 | 2010 | 1995 | 2010 | 1995 | 2010 |
| United States | 16.1 | 10 | 14.6 | 15.6 | 19 | 15.2 |
| EU | 11.2 | 6.9 | 47.6 | 44 | 17.3 | 15.7 |
| Japan | 22.1 | 6.7 | 4.3 | 2.3 | 19.2 | 6.5 |
| China | 6.5 | 31.4 | 3.5 | 3.9 | 6 | 22.3 |
| Asia-8 | 36.3 | 36 | 3.5 | 6.4 | 27.3 | 27 |

Source: Bruegel based on National Science Foundation data (NSF, 2012). Note: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand. Among high-tech sectors, ICT accounts for 61 percent of all high-tech exports. For a breakdown of knowledge-intensive sectors, see Annex 2.

4. The trends for high-tech manufacturing sectors only (not shown) are similar but even more clear.

be 59 percent, while for Japan, the EU15 and the US, it is more than 75 percent.

This correction for foreign content holds particularly for high-tech goods, because global value chains are prevalent in high tech sectors such as ICT, and much of the value of final products is embedded in components and design.

Table 5 shows the foreign value added share in gross exports for high tech goods. It shows that: i) high-tech exports have a high share of imported content, particularly in China and Korea (column 3); ii) for most countries the foreign value added intensity is much higher in high-tech goods than for the overall economy (column 4). This is particularly the case for China; iii) the foreign share in high tech has been increasing over time for most countries (columns 2-3), but especially in China (no data for 1995 available for Korea).

All this suggests that the rise of China and to a lesser extent Korea in high-tech exports and the declining shares for the US, Europe and Japan, need to be properly adjusted for the role these countries play in international value chains of high-tech goods, particularly ICT. The case of Apple's iPad is illustrative (see Annex 3). China, which merely assembles and then exports the final product is credited with the full value of the factory price (plus shipping costs) in gross value trade statistics, but its domestic value added, being mainly an assembler, is tiny and hence its contribution is much smaller than other countries which supply inputs and manufacture components.

**Table 5: Foreign value added in gross exports for high-tech goods**

| | % of foreign value added in gross exports of high-tech goods (1995) | % of foreign value added in gross exports of high-tech goods (2005) | % of foreign value added in high-tech goods relative to all goods (2005) |
|---|---|---|---|
| China | 20.1 | 48.5 | 1.77 |
| Korea | | 46.3 | 1.21 |
| Japan | 10.0 | 21.5 | 1.41 |
| US | 16.6 | 17.4 | 1.62 |
| France | 29.1 | 29.2 | 1.07 |
| Germany | 24.1 | 31.2 | 1.12 |
| UK | 33.6 | 32.3 | 1.62 |

Source: Bruegel based on IMF (2011).

Properly factoring in China's role as the assembler of high-tech goods and crediting exports to countries on the basis of their domestic value added contribution would reduce the trade deficit that many countries have with China[5], particularly those countries which design and produce high-value components. At the same time, China and other south-east Asian countries also manufacture components for high tech goods that are assembled elsewhere. In this case, these countries' value added is attributed elsewhere. IMF (2011) analysis shows how the growth of high-tech exports from the US, EU15 and Japan was almost entirely driven by growth in foreign value added and how significant China's contribution has been, through the manufacturing of intermediate components, to the growth of these countries's high-tech exports. All this signals the significance of global value chains, with major impacts on countries' trade structures, blurring the analysis of export data for assessing competitiveness. What matters is where value added is created and where it is captured. On this, the case of the Apple iPad makes clear the critical role of who holds key property rights, and controls design and marketing. In the iPad case the US still captures the major part of the value added, although it has almost entirely outsourced the manufacturing, retaining only a small manufacturing base producing critical components. The value captured by the US is mostly related to design and marketing.

## MAIN FINDINGS

A previous Bruegel publication, ('A G2 for science', *Policy Brief* 2011/03), concluded firmly that China is on the rise as a science powerhouse. Although other countries, such as South Korea, are also catching up, the Chinese emergence in science is uniquely rapid, particularly in engineering, chemistry and physics. 'A G2 for science?' also documented a China-US connection which is virtuous, mutually beneficially, so far robust and more or less unique, predicting a future science landscape that will look more like a G2 than a truly multipolar system, with the attendant risk that Europe and

5. Xing (2010), crediting exports on the basis of value-added contribution, estimates that this would reduce the value of China's exports of Apple iPhones to the United States in 2009 from an estimated $2 billion to less than $100 million.

other countries will be sidelined. Can we extend this prediction into an emerging G2 for innovation as well?

The evidence presented in this Policy Contribution clearly shows that there is an increase in Asian R&D investment. As in science, China is now the second R&D spender, after the US, bypassing Japan. Although the EU as a bloc spends more than China, China has already the combined size of Germany, France and Italy. Although China's rise is again very robust and rapid, and is likely to continue, in common with China's science growth, other south-east Asian countries are also rapidly increasing their R&D spends. This holds most notably for Korea, while Japan is an incumbent R&D stronghold and India is lagging. Most new Asian R&D investment, even if it comes mainly from the private sector, is backed by targeted public support.

This growth in Asian R&D investment is translating into increasing patent filings. In fact, Asian countries have grown even faster in patenting than in R&D investment. But although the increase in China's share of world patent applications has risen faster than its share in world R&D expenditure, it is still only a minor player in patent terms, with the same impact as much smaller Korea. And when looking at the most valuable inventions, ie those for which patent protection in sought in all major world markets, China's share remains tiny.
This Asian growth in R&D spending and patents is very much focused on ICT, an area with high technological opportunities and positive externalities acting on other sectors. In other technologies with high growth potential, such as clean technologies and nanotechnology, the global playing field remains open. World markets for pharmaceuticals remain as dominated by the EU and US.

When looking at the economic value created by innovative new goods and services, all of the countries with major R&D expenditure are increasingly concentrating their economic activities in knowledge intensive goods and services. In this respect, the US is the most specialised and China the least, with the EU inbetween. Furthermore, each region specialises in different high-tech sectors. While the US and Europe relocated ICT manufacturing to Asia, the services and the pharmaceuticals sectors remain Western strongholds. China's dramatic increase of exports of high-tech goods, particularly ICT goods, might seem impressive, resulting in widening EU and US trade deficits with China for these goods. But as the Chinese role is still mostly assembly, with less value added contributed locally, China is not (yet) capturing much value from high-tech manufacturing. It is not yet capitalising on its rising science and technology capabilities in these areas. There is still considerable scope for value capture of clever foreign innovators, designing global value chains, as the example of Apple's iPad illustrates. Overall, although the Asian, and particularly, but not uniquely, the Chinese rise in technology and innovation is a real phenomenon, it is still far less materialised than Asia's rise in science. Innovation capacity is spread across more Asian countries than just China, resulting in a more multipolar innovation landscape than in science. In addition, China still has to prove itself as a developer of high-value inventions for world markets, beyond ICT manufacturing. And it still has to capture the value from inventions beyond assembly.

It would be wrong to discount the Chinese innovation potential on the basis of current performance. China clearly has the ambition to become a world-leading innovator, creating and capturing high-tech value added, particularly in targeted areas. But it would be equally wrong to see the rise of China and other Asian countries in innovation – a trend that is likely to continue – as a threat to Europe. The innovation landscape is and should be truly global, with innovators able to exploit science, technology and manufacturing capacity and serve new needs wherever they are located. Innovation is furthermore not a zero-sum game. Spillovers from innovation capacity wherever located can be exploited by European innovators in co-optition (a delicate balance between cooperation and competition) with Asian and American innovators. Nevertheless, the opportunities that the globalisation of R&D and innovation can offer to Europe cannot be taken for granted. As the data has shown, Europe is struggling more than the US to build technology strongholds in knowledge intensive goods and services, particularly in new areas and with high quality new technology. Europe needs to step up its investments in innovation capacity if it wants to keep its seat at the global innovation table. Although this is a call to all European countries, it holds especially for countries such as Italy as a large developed yet low-innovating nations.

The most relevant issue for the EU is not so much if Asia's science, technology and innovation capacity will continue to increase, but who will be able to use this capacity for value creation and value capture? Corporate R&D and innovation is highly concentrated in a few big global players. How these firms react to and ride on the Asian science and technology rise will be critical for answering this question and hence assessing the impact on Europe.

## REFERENCES

Balassa, B. (1965) 'Trade Liberalisation and Revealed Comparative Advantage', *The Manchester School* 33: 99-123

Dalum, B., K. Laursen and G. Villumsen (1998) 'Structural change in OECD export specialisation patterns: de-specialisation and "stickiness"', *International Review of Applied Economics* 12: 447-467

European Commission (2012) 'The EU industrial R&D investment scoreboard', *JRC Scientific and Technical Research Series*, JRC-IPTS, available at http://iri.jrc.ec.europa.eu/reports.htm

Harhoff, Dietmar, Frederic M. Scherer and Katrin Vopel (2003) 'Citations, family size, opposition and the value of patent rights', *Research Policy* 32(8): 1343-1363

IMF (2011) *Changing patterns of global trade*, Washington DC

Koopman, Robert, William Powers, Zhi Wang and Shang-Jin Wei (2010) 'Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains', *Working Paper* 16426, NBER

NSF (2012) *Science and Engineering Indicators 2012*, National Science Foundation, available at http://www.nsf.gov/statistics/seind12/pdf/seind12.pdf

OECD Statistics website, Science, Technology and Patents section, available at http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC

Van Pottelsberghe, Bruno (2008) 'Europe's R&D: Missing the wrong targets', *Policy Brief* 2008/03, Bruegel

Veugelers, Reinhilde and Michele Cincera (2010) 'Europe's missing yollies', *Policy Brief* 2010/06, Bruegel

Veugelers, Reinhilde (2011) 'A G2 for science', *Policy Brief* 2011/03, Bruegel

Xing, Y. (2010) *How the iPhone widens the United States' trade deficit with the People's Republic of China*, Asian Development Bank Institute

## ANNEXES

### *Annex 1: Revealed Comparative Advantage Index*

Revealed Comparative Advantage Index (Balassa, 1965): a country's share of world total in a sector relative to the country's share of the world economy:

$$RCA = \frac{\dfrac{X_{i,j}}{\sum_i X_{i,j}}}{\dfrac{\sum_i X_{i,j}}{\sum_{i,j} X_{i,j}}} \quad i = \text{sector},\ j = \text{country}$$

Revealed Symmetric Comparative Advantage Index (Dalum *et al*, 1998):

$$RSCA = (RCA-1)/(RCA+1)$$

### *Annex 2: Knowledge-intense sectors*

The Organisation for Economic Cooperation and Development has identified ten categories of industries that have a particularly strong link to science and technology.

- Five knowledge-intense service sectors that incorporate high tech either in their services or in the delivery of their services: financial, business and communications services (including computer software and R&D, and two non-commercial services: education and health services.
- Five high-tech manufacturing industries that spend a large proportion of their revenues on R&D and make products that contain or embody technologies developed from R&D. These are aircraft and spacecraft, pharmaceuticals, computers and office machinery, semiconductors and communications equipment, and scientific (medical, precision, and optical) instruments.
  - ICT combines the High Tech manufacturing industries of computers and office machinery, communications equipment, and semiconductors with the Knowledge Intensive services of communications and computer programming (a subset of business services).

While production data are classified by industry affiliation of the firm, trade data are classified by product or type of service. An export classified as a computer service may originate from a firm classified as a computer manufacturer. Trade data also cannot provide a precise measure of where value is added to a product or service. For example, China is credited with the full value (ie factory price plus shipping cost) even when exporting a smart phone that was assembled in China with inputs and components imported from other countries. Countries whose firms provide these high-value components and services (design, marketing, software development, etc) are not credited for their contributions.

### *Annex 3: Who creates and captures the value of global high-tech products? The case of Apple's iPad (adapted from NSF, 2012)*

Several case studies have attempted to estimate more precisely the geographic contribution of the global value chain involved in the production of several high-tech goods. These studies show that the greatest returns accrue to the firms and countries with design, engineering and marketing expertise (see NSF, 2012, for further references).

The case of Apple's iPad (see table on the next page) shows that the United States receives 33 percent of the retail price of the iPad, almost all of it (30 percent) consisting of Apple's gross profit.

The estimated share for manufacture and assembly of components for the iPad is 23 percent, largely apportioned to South Korea with smaller distributions to Japan, Taiwan, the EU and the US. China, the location of final assembly, receives an estimated two percent share of the iPad's price. China's value added is very small because final assembly of these products requires only a few minutes and China's wages for assembly workers are (still) very low compared to those in more developed countries.

**Value chain of Apple iPad, by location and activity: 2010**

| Characteristic | Activity | Location | Amount/cost (US$) | % of retail price |
|---|---|---|---|---|
| Distribution and retail | Manufacturer's suggested retail price | Worldwide | 499 | 100 |
| | Distribution | Worldwide | 75 | 15 |
| | Wholesale price (received by Apple) | United States | 424 | 85 |
| Value capture | Total value capture | | 238 | 47.7 |
| | U.S. total | United States | 162 | 32.5 |
| | Design/marketing | Apple | 150 | 30.1 |
| | Manufacturing of components | U.S. suppliers | 12 | 2.4 |
| | Manufacturing of components | Japan | 7 | 1.4 |
| | Manufacturing of components | South Korea | 34 | 6.8 |
| | Manufacturing of components | Taiwan | 7 | 1.4 |
| | Manufacturing of components | EU | 1 | 0.2 |
| | Manufacturing of components | Unidentified | 27 | 5.4 |
| Direct labour | Total direct labour | | 33 | 6.6 |
| | Labour to manufacture components | Unidentified | 25 | 5 |
| | Labour for final assembly | China | 8 | 1.6 |
| Inputs | Nonlabour costs | Worldwide | 154 | 30.9 |

Source: NSF (2012).